A Global Modeler Looks at Regional Climate Modeling

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Global climate models consist of global representations of the atmosphere/land surface/oceans and sea ice. The global climate state simulated by such a model is determined largely by the sources and sinks of energy and water on the global scale. Typical global models used for climate research today have horizontal grid spacings on the order of 200-300 km. Within the next five years, these grid spacings are likely to decrease to about 100 km.

Applications of global climate models include understanding basic climate processes and simulation of the response of the climate system to variable external forcing, notably including anthropogenic forcing. Depending on the application such models are run for periods of a few simulated years, out to a few simulated centuries. In the next five years, even longer runs will become commonplace.

Regional climate models typically have domains a few thousand kilometers on a side and include representations of the land surface, but not the oceans. Many such models have horizontal grid spacings on the order of 50-100 km. For purposes of this talk, I will consider only those regional climate models that are driven at their boundaries by the output of global climate models. There are various ways to do this, but in all cases, the regional energy and moisture budgets are largely determined by the global model. In what sense, then, can a regional climate model be used to study climate? The utility of regional climate models arises from the importance of regional climate forcings. There are many such forcings, including topography, land-water contrasts, and urbanization and other human influences. Such forcings can produce strong regional climate phenomena such as orographic precipitation and lake effect precipitation, which are potentially predictable and which can change in response to changes in the global climate state.

In both global climate models and regional climate models, the results are strongly dependent on parameterizations of cloud processes, radiation, turbulence and land-surface processes. It is of course important that the parameterizations of a regional climate model be physically consistent with the real world and also with the parameterizations of the global climate model that provides the boundary forcing. Many parameterized processes can be expected to behave differently as the grid spacing is reduced from hundreds of kilometers to tens of kilometers. An obvious example is deep cumulus convection. What does it mean to parameterize deep convection in a model with grid boxes, not much larger than cumulonimbus clouds? Clearly when the grid size becomes sufficiently small, all clouds become “stratiform.” We might, therefore, expect that regional climate models, with their relatively fine grids, need parameterizations that are more sophisticated than the parameterizations used in global climate models. This requirement conflicts, however, with the previously stated need for consistency between the parameterizations of the regional and global models. We are thus led to the question: Is it possible to develop parameterizations, for example of cloud processes, which “scale” in the sense that they can be used in both low-resolution and high-resolution climate models?

As an emissary from the global climate modeling community, I wish to report that there is already interest in that community in the possibility of representing both cumulus and stratiform clouds with a single, unified cloud parameterization. This development has been motivated by the recognitions that on the one hand, many stratiform clouds are produced by detrainment from cumulus clouds, while on the other hand virtually all stratiform clouds are filled with moist convective turbulence. Cumulus and stratiform clouds can therefore be thought of as idealized end points on a continuum, and real clouds are typically found somewhere between the end points.

Since regional climate models have, if anything, a greater need for such a unified cloud parameterization than global climate models do, it would be natural for the regional climate modeling community to begin to lead the way toward the development of the next generation of parameterizations for use in both regional and global climate models.